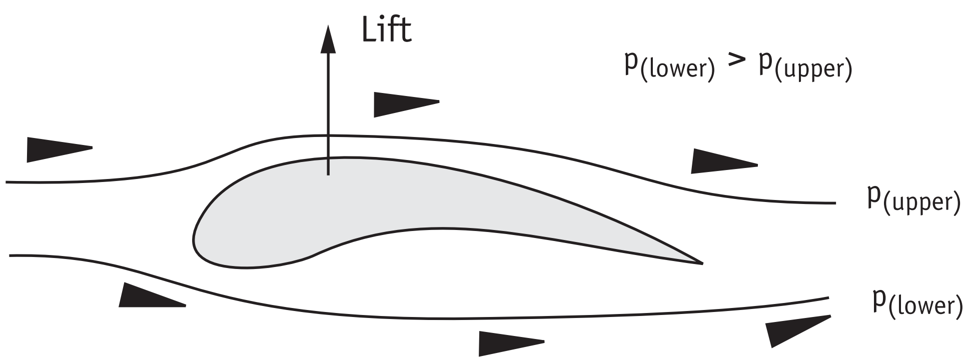
Activity II: Physics of Flight

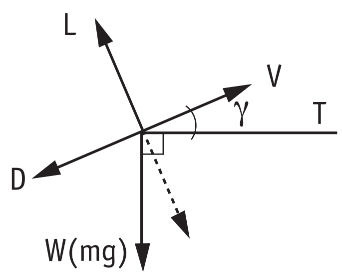
Introduction

In order for air traffic controllers and other pilots to monitor and predict where airplanes are flying, pilots must fly within a flight path, as proposed in their flight plan. To ensure safety, air traffic controllers sometimes ask pilots to make adjustments to their course, altitude, or even air speed. Changing speed requires an understanding of the physics of flight, which is explained (in its most simplified form) below.

A general wing with air flow above and below it.:



Lift of the wing occurs because the pressures below and above the wing differ. $p_{upper} < p_{lower}$, allowing lift to occur. (Note: there is some controversy about this.)



$\angle\gamma$ = flight path angle

L = Lift, V = Velocity, T = Torque, D = Drag, W = Weight,
m= mass, g = gravity

We can combine these vectors to determine the net force on the airplane.

$$T - D - W\sin\gamma = F_{net}$$

$\mathbf{V}$ denotes V-dot, or rate of change of speed.

Because $W = mg$ and $F_{net} = m\mathbf{V}$,

$$T - D - (mg)\sin\gamma = m\mathbf{V}$$

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Flying results in a change in speed. In order to see this rate of change of speed, we set the equation equal to **V** .

$$\mathbf{V} = \frac{T - D}{m} - g \sin\gamma$$

Because mass will vary depending on the angle of elevation,

$$\mathbf{V} = \frac{T - D}{m \sin(\gamma)} - g \sin\gamma$$

1. For the following flight path angles, determine the rate of change in speed if $T = 1.80 \times 10^4$ N, $D = 1.12 \times 10^4$ N, $m = 6.00 \times 10^3$ kg, and $g = 9.8$ m / s^2.
   a) $\gamma = 1$
   b) $\gamma = 5$
   c) $\gamma = 10$
   d) $\gamma = 30$
   e) $\gamma = 45$
   f) $\gamma = 90$

2. How does rate of change in speed alter as the flight path angle increases? Be specific.

3. If flight angle is 0°, you might expect rate of change of speed to be higher than the example given in question 1.
   a) Solve and explain if this is the case.

   b) Draw a line graph summarizing your findings of flight angles and rate of change of speed.

4. What do you notice about gravity when flight path angle is 0°? 90°?

5. At what angle would the rate of change in speed be 0?

Torque (T) depends on the throttle position, which is anywhere between 0 (no throttle) and 1 (full throttle and maximum Torque or Thrust (T_{max})). Throttle(η) and Torque are related via the following function:

$$T = \eta T_{max}$$

6. For the same conditions as before and a flight path angle of 5°, determine the rate of change in speed for the following throttle positions, if T_{max} is 1.0×10^5 N or 1.0×10^5 kg m/s^2.
   a) $\eta = 0$
   b) $\eta = .10$
   c) $\eta = .25$
   d) $\eta = .50$
   e) $\eta = 1$

7. What generalization can you make about the throttle position and the rate of change in speed of the airplane?

8. What happens when the throttle is 0? How does the airplane travel when this occurs?

9. At what throttle position would the airplane appear to stall or stop in midair? Assume the flight angle is 5° and all else is the same as in question 6.

10. For the same conditions as those previously mentioned, EXCEPT mass of the airplane, with a flight path angle of 5° and throttle position of 0.5, with T_{max} = 1.0×10^5 kg m/s^2, determine the rate of change in speed of the airplane with the given masses.
    a) m = 7×10^3 kg
    b) m = 1×10^4 kg
    c) m = 9×10^4 kg
    d) m = 2×10^5 kg
    e) m = 4×10^5 kg

11. a) At what mass does the rate in change of speed become
    i) negative
    ii) positive
    iii) zero

    b) When rate of change in speed is negative, how is the airplane moving?

    c) When rate of change in speed approaches zero, how is the airplane moving?

12. If one were to fly an airplane on a different planet, then one would have to consider gravity as a crucial factor in keeping an airplane airborne. Following is a chart with gravity values for several planets. If we were to fly our airplane with all original characteristics INCLUDING MASS, on these different planets, what would their rates of change in speed be? Assume throttle position is 0.5 and T_{max} is 1.0×10^5 kgm/s^2.

Planet	g(m/s^2)*	*V*
Mercury	3.78	
Venus	8.60	
Mars	3.72	
Jupiter	22.9	
Saturn	9.05	
Uranus	7.77	
Neptune	11.0	
Pluto	0.03	

* Gravity as measured at the planet's equator.

13. When gravity is greater than that on Earth, what happens to the rate of change of speed?